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AN APPARATUS FOR THE MEASUREMENT OF PHOTOELECTRON EMISSION CURRENT WITH ON-LINE COMPUTER DATA ACQUISITION.

Part I. Description of Cell and Operational Procedures.

~~Iwao Watanabe~~

Part II. Electronics, Computer Interfacing and Programming.

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INTRODUCTION

Described herein is a new apparatus designed to obtain quantum yield data (i.e., photoelectron emission current as a function of exciting wavelength) for liquids or solutions of moderately high ($\sim$ 5 torrs) vapor pressure, in the UV and VUV range up to 10.5 eV photon energies. Novel features of the apparatus include high sensitivity in the presence of high vapor density and on-line computer data acquisition and analysis.

The apparatus achieves high sensitivity by use of a very small gap ($\sim$ 1 mm) between the emitting surface of the liquid and the grid which captures the electrons. Such a small gap minimizes losses due to gas phase light absorption since the space between the collector and liquid emitter is maintained at the equilibrium pressure of the liquid.

Use of the on-line computer has a number of advantages for this experiment:

(1) Yield curves, calculated by dividing photoelectron emission current by photon density, are generated quickly and plotted within seconds after an experiment is completed.

(2) Data are stored permanently on a computer-readable medium (floppy disk).

(3) Data can be subjected to mathematical analysis of various sorts long after the experiment is done.

Figure 1 shows a simplified block diagram of the experimental setup, with emphasis on data paths and signal handling. As seen in Fig. 1, the total apparatus consists of several main sections: cell compartment, computer, monochromator, light source, cell current amplifier and associated electronics, photomultiplier (PMT) and electronics, scan drive relay circuit, and temperature control circuits. The following sections detail the various components of the system.

PART I

CELL DESIGN

The cell design is predicated on several considerations:

(1) Short path for incoming photons and emitted electrons through the gas phase.

(2) Chemically inert support for the film of solution.

(3) Rapid renewal of surface (age of the liquid film at the point of illumination is 500 msec).

(4) Operation at equilibrium vapor pressure of the solvent to prevent freezing and concentration inhomogeneity due to evaporation.

(5) Efficient and accurate temperature control.

(6) Warming of the LiF window in the sample chamber to prevent condensation of solution and inhibit attack of the window.

(7) Good reproducibility of liquid surface to collector grid distance, independent of viscosity of the solvent.

Figure 2 shows water vapor absorption and transmittance spectra calculated for 1 mm path and 5.1 torr, corresponding to the equilibrium vapor pressure at 1.5^{o}C.[1] The short path for the photons up to 10 eV makes it possible to provide quantum yield data even for aqueous solutions. The design of the cell compartment is shown in Fig. 3 and its detail will be described part by part.

<u>Photon Intensity Monitor</u>. A wire (0.02" dia), B in Fig. 3, coated with sodium salicylate is horizontally placed 1 cm behind the exit slit, intersecting a small portion of the photon beam for monitoring purposes. Because of the horizontal wavelength dispersion of the monochromator, the spectral distribution at the wire should be similar to that at the target. The fluorescent light from the coated wire is detected with a photomultiplier at a right angle to the photon beam, through a vacuum-tight glass window. The details of the electronics will be described in later sections.

LiF Window and Grid Electrode. After the monitoring of its intensity, the photon beam passes through a LiF window (H in Fig. 3) and a grid mesh electrode (I). The electrode made of gold is supplied with an accelerating voltage of +10 to +250 V. The mesh electrode (from Buckbee-Mears Co.[2]) is 80% transparent. It is in contact with the LiF window which is fixed with Apiezon W wax onto a holder made of brass (G). The edge of the grid mesh is treated with silver paint to make electrical contact with the holder. The brass holder has two 1/8 W 2 kΩ resistors in parallel supplied with 30 V for heating, and a small glass bead thermistor for temperature monitoring.

The thermistor indicated that the temperature of the holder was around 45^{o}C during the experiments. The heating of the window was essential to keep the window dry. Preliminary experiments without heating the window indicated that after a few runs with aqueous solution the photoionization current could be increased by the use of a hot air blower at the window. The brass holder itself is electrically and thermally insulated from the slit and photomultiplier assembly through a rubber O-ring and plastic cylinder with screw.

Liquid Cell. The liquid cell is composed of a Pyrex glass liquid reservoir, a glass rotating disk, a glass tube dipped into the liquid as a cooling unit, a thermistor, and a platinum wire electrode. The reservoir is glued to a Teflon support which hooks to the brass plate. The hooks hold the reservoir in position and make the changing of solutions easy. The glass rotating disk, 52 mm dia. and 2 mm thick, is attached on an acrylic plastic shaft with Torr Seal epoxy. The disk is immersed in the solution up to a few mm under the plastic shaft.

The solution is cooled by a glass tube through which nitrogen gas cooled by dry ice-alcohol or liquid nitrogen passes. An electromagnetic gas valve controlled by a thermistor bridge circuit regulates the passage of cooled nitrogen gas which keeps the temperature of the solution constant. Since the solution is connected to a very high impedance input of the current amplifier, the thermistor circuit is completely floated from ground and shielded in order not to bring outside electrostatic noise to the solution. The floating of the

circuit is achieved by the use of an internal battery power supply and an optical coupler. The electrical circuit diagram will be shown in a later section. In order to avoid liquid condensation on the cooled glass tube, which might electrically connect the solution to the ground, the parts of the tube outside the solution are covered with thick Diflon plastic tubes.

Glass Disk Rotation and Distance Adjustment Mechanism. The disk is rotated at a rate of 0.5 rps by the use of a 60 rpm electrical motor and a 2:1 ratio speed reducer (E in Fig. 4). The output of the reducer is connected through a flexible coupler to the drive shaft on which the glass disk is attached. The shaft is held in place through two O-rings to a sliding block (B) having a screw mechanism which produces 0.5 mm displacement by each turn of a case (C). The movable parts are doubly sealed with O-rings and the space between them is evacuated by rotary pump to serve as differential pumping.

Distance Adjustment Procedure. There are several causes which make the distance measurement between the grid electrode and the glass disk liquid film difficult. They are: irregular shape of grid mesh; imperfections of parallelism of the glass disk and the LiF window; and the nonplanar shape of liquid film on the glass disk which is determined by the combined effects of gravity, centrifugal force, viscosity, ripple in the liquid cell, and probably electrostatic attractive force. It is very difficult and inconvenient to measure the distance from outside by means of a cathetometer. Instead of using a visual technique, an electrical distance-determining method was used. The lock-in amplifier used to measure ionization current can also provide a reference output of the same frequency at which a bandpass filter in the amplifier works. The high voltage source is disconnected and the reference output (0.9 V, 12 Hz) is applied to the grid electrode. All the other circuits remain in the same configuration as for the ionization current measurement, and are used to amplify the capacitive current. Since the capacitance (c) of parallel plates is inversely proportional to the distance between the plates, the extrapolation of a linear plot 1/c vs. distance should provide us an accurate distance measurement. The calculated capacitance composed of parallel plates in vacuum, 1/2" dia. and 1 mm apart, is around 1 pF. The experimental results shown in Fig. 5 indicate the plot is not linear. The liquid on the disk touched the grid electrode well before the

extrapolated zero point. The liquid contacts often occurred around the point B in Fig. 5 where one could still see more than a few tenths of a millimeter clearance by visual measurement. In order to avoid accidental liquid contact which may greatly alter the LiF window transmission characteristics, the glass disk must be kept at more than 0.5 mm from the grid, and the distance normally used was ~ 1 mm. The distance was arbitrarily chosen so that the capacitive current gave 60 mV output at a current-voltage converter with 10^{10} feedback resistor. Before each experiment, the position of the disk was adjusted to give the same capacitive current, in order to compensate the small liquid film thickness change depending on viscosity and O-ring deformation.

Pumping System and Pressure Measurement. Two mechanical rotary pumps are used. One with liquid N_2 trap evacuates the ionization cell chamber and has a three-way stopcock which closes the chamber after evacuation and introduces air after taking a spectrum. The other one serves as a means of differential pumping at the rotary feedthroughs for the UV light chopper and for the target disk. In order to measure the vapor pressure in the chamber, an oil manometer is used which is filled with silicone diffusion pumping oil to avoid mercury vapor contamination. The density of the oil is 1.0864 g/cm^3.

Experimental Procedure. It is very difficult to maintain the glass disk surface in a water-wetted condition. Even if the glass disk has been kept rotating for a day in vacuum, whether it has been dipped in water or not, parts of the disk lose their wetability. Therefore, it was very important to clean the disk every day with hydrofluoric acid. Since the hydrofluoric acid is one of materials having high photoionization cross section, thorough washing with pure water must be followed after the cleaning. New aqueous solution should be introduced into the cell only after the quantum yield spectrum of pure water shows no photoionization current below 9.5 eV. Solutions were introduced into the cell without prior degassing. There is little bubbling or splashing of solution if the aqueous solutions are cooled down to a few ^{o}C before the cell chamber evacuation begins. The evacuation process from atmospheric pressure to ultimate vapor pressure must be done slowly (about 10 minutes total) to avoid splashing.

MONOCHROMATOR

The vacuum UV monochromator used was the GCA/McPherson Model 235 0.5 meter scanning monochromator equipped with Model 815 Pumping Control System. The characteristics of the vacuum system and details of the monochromator are given in ref. 3.

The monochromator is of the Seya-Namioka type with the grating as the only reflecting surface between source and target. Grating specifications are as follows: concave focal length = 0.25 m; 1200 L/mm; reciprocal linear dispersion 17 A/mm; coating, $AlMgF_2$; grating area with mask, 2 x 3 cm; without mask, 3 x 5 cm.

The pumping system consists of a Sargent-Welch Model 1397 Duo-Seal two-stage rotary pump,[4] and Varian/NCR M4 4" oil diffusion pump.[5] The Model 815 control system provides control for the electro-pneumatic valves as well as safety interlocks for the entire system.[6] The pumping system is capable of producing a vacuum of better than 10^{-7} torr in the monochromator as indicated by the discharge gauge of the Model 815.

ELECTRONICS: CELL TO COMPUTER

The electronics associated with the amplification of the photoelectron current are shown in Fig. 6. The solution is maintained at virtual ground by a high-gain current to voltage converter. Contact with the solution is made through a platinum wire dipped in the solution container. The feedback resistor is currently 10^{10} ohms. The operational amplifier is Burr-Brown type 3420 with variactor input.[7] As shown in Fig. 6, this DC amplifier is followed by a bandpass filter,[8] the electrical schematic of which is shown in Fig. 7. This filter is particularly important when high sensitivities are required as a result of low emission currents. The light is chopped before entering the monochromator at a frequency of 12 Hz. The phase sensitive detector (Princeton Applied Research, Model 121)[9] detects only the component of the cell current corresponding to 12 Hz. The bandpass filter is necessitated by the fact that the input amplifier stage of the PAR detector is

not tuned. Thus, at high sensitivity, signal of all frequencies are amplified before going to the tuned circuitry. If large components at frequencies other than 12 Hz are present, the input amplifier stages will saturate. The bandpass filter therefore reduces these frequencies so that the PAR detector will work properly.

During data acquisition, the PAR phase sensitive detector is operated in the "selective external" mode. In this mode, an external reference signal of arbitrary amplitude and shape is used to synchronize the rectification of the chopped signal into a DC signal suitable for the computer. The output is ± 10 V full scale, so that further amplification or processing of this output is not necessary before sending it to the computer A-to-D.

In order that yield curves from one experiment to the next be comparable, it is necessary to carefully adjust the controls of the PAR detector as described in the manual of operations.[9] Adjustments include: reference channel frequency; signal channel frequency; reference channel attenuation; phase; and time constant. Since the bandpass filter introduces an appreciable time constant of its own, there is no advantage to using a time constant of less than 1 sec. From the PAR detector, the signal travels to the computer A-to-D converter through a 30-foot shielded cable with twisted pair conductors.

ELECTRONICS: PHOTOMULTIPLIER CHANNEL

The photomultiplier channel provides a reference light intensity so that quantum yield can be calculated. Figure 8 shows a block diagram of the signal path. A portion of the chopped vacuum UV light is intercepted by a wire coated with sodium salicylate crystals (applied as a saturated solution in 95% ethanol by airbrush).[10] The salicylate fluorescence is in the blue region of maximum sensitivity of the Hamamatsu TV Model 347R photomultiplier tube.[11] The signal is amplified (Fig. 9) by a simple op-amp circuit. The output of the amplifier is sent to the Keithley Model 822 phase sensitive detector. The output of the first amplifier also controls the high voltage supply for the tube. If the output of the amplifier exceed 8 volts, the

circuit shown in Fig. 10 will instantly interrupt the high voltage to the tube, thus protecting it from damage when high light intensities are accidentally encountered when the voltage supply is on.

The Keithley phase sensitive detector, Model 822,[12] is a much simpler device than the PAR detector described above. There is no control of sensitivity or phase angle, so that the former is controlled by photomultiplier voltage, and the latter by mechanical adjustment of the reference chopper. The output is ± 10 V, so that interfacing with the computer A-to-D converter is direct.

The high voltage supply is Harrison Model 6525A, manufactured by Hewlett Packard.[13] In order to keep calculated yield comparable, it is important to operate this at a constant voltage from day to day. For our present work, we usually use 440 volts, which, after amplification and phase sensitive detection, yields a maximum output of 3-7 volts (1600 A).

REFERENCE CHANNEL

Use of the two phase sensitive detectors requires a waveform synchronized with the chopper for reference purposes. Figure 11 shows schematically the design of the reference chopper and the amplifier circuit. The reference chopper is mounted on a common shaft with the UV chopper. Modulation is achieved by a bladed disk which periodically passes between the emitter and detector of an optical switch (Monsanto MCT81).[14] This optical switch is mounted on a hinge so that the phase angle may be adjusted mechanically. Power is supplied by four 1.5 V alkaline batteries in order to avoid ground loop problems which were encountered with an ordinary transformer supply. The output of the amplifier is sufficient to drive several loads at 6 V.

<u>Monochromator Scan Drive</u>. The GCA/McPherson Model 235 monochromator has provision for external control of the scan drive motor on/off function. In order to start the scan drive at the same instant that data collection begins, a circuit was built which allows computer control of this function. In Fig. 12 we see that a single TTL bit from the DR11-M digital output is amplified

and used to drive a relay which enables the monochromator scan. Note that all other controls - scan direction and speed as well as initial wavelength - must be manually set by the operator.

Temperature Control. A thermostatting apparatus was built in order to produce a reproducible low temperature of solution. The temperature sensor is a small thermistor (Fenwal Electronics, type GB41P2) dipped into the solution. Cooling of the solution is achieved by passing a stream of cooled nitrogen gas through a glass cooling tube. The use of gas rather than liquid coolant prevents electrical noise which might be introduced by the liquid. The rate of cooling of solution is governed by controlling the gas flow with an on/off valve. A block diagram of the cooling train and control circuitry is shown in Fig. 13. Electrical schematics are in Figs. 14 and 15.

Lamp and Chopper Assembly. The hydrogen lamp is essentially the same as described previously.[15] Between the lamp and the monochromator are three flanges supporting a shutter, filter elements, the entrance slit, the chopper, and two lithium fluoride windows. The external appearance of this assembly is shown in Fig. 16. A cutaway view is shown in Fig. 17.

The shutter interrupts the light from the lamp in order to save the window material from unnecessary exposure. The filter assembly provides a choice between glass, sapphire and Suprasil filters. The first lithium fluoride window is not glued in place; its purpose is to protect the second window, which acts as a high vacuum seal for the monochromator, from degradation by plasma and high energy photons from the lamp. The first window is replaced after each one-hour period of exposure. Windows used in this position are cleaned with organic solvents and baked at 500°C to remove F-centers. They may be reused several times. Windows used at position 2 are usually fresh from the manufacturer and may be used for several weeks before changing is necessary.

The UV chopper is made from a 1" tube of brass with six 1/4" slots milled at spacings of 60° around the circumference. The shaft rotates at 120 RPM, resulting in a chopper frequency of 12 Hz. Differential pumping is provided for the shaft feedthrough to prevent contamination of the hydrogen lamp by air.

Computer Program. The program used for data acquisition ("YIELD") was written mostly in Fortran with a few subroutines for operation of the A to D converter, digital input/outputs and real time clock written in assembler language. The current program allows for data acquisition as well as plotting for either one or two data sets. Each data set corresponds to a single scan of the monochromator. Data sets are stored on floppy disks from which they can be retrieved at any time for plotting or analysis. Figure 18 shows a flowchart of the program YIELD.

Figure 19 shows in more detail the steps involved in taking experimental data and recording it on a disk file. The sequence is as follows: The file is named and the computer allocates buffer space in memory for the data; the operator then enters one line of identifying text to be recorded with the data on the permanent file. The operator then enters initial wavelength, final wavelength, scan rate and PAR scale. These are the only parameters necessary for the computer to calculate the yield curve. Of course, the operator must insure that all other factors which affect the yield curve are in good order.

With the shutter closed, the computer than takes "baseline" points - the voltages corresponding to the zero light levels for both the cell current and photomultiplier current. The shutter is then opened and the wavelength scan commenced under computer control. Points are presently taken at one per second for fast scans or at a slower rate for slow monochromator scans. The sample rate is adjusted so that a maximum of 500 data points is taken per experiment. At the end of the scan, the scan drive motor is turned off under computer control. The data are recorded permanently on floppy disk. The operator may then examine the raw data or the calculated yield data. It is also possible to compare two different data sets on the same scale. In this mode, it is possible to compare raw photoelectron emission current, photomultiplier current, calculated yield curves, log yield, as well as the ratio and difference of yield for two different data sets.

COMPUTER

The laboratory computer used is a PDP 11/34[16] equipped as follows (see Fig. 20): 32 k words (16 bit) solid state memory; KW11 real time clock; DR11-CK digital input/output; DR11-M two-word digital output; Plessey DL11-WA teletype interface; AD11 16-channel A/D converter; RX11 dual floppy disk drive; VT55 graphic terminal with hard copy unit. The programming was done in Fortran and assembler language under an RT-11 operating system. The only mass storage device was a floppy disk.

Analog input from the experiment was accepted by the AD11 analog to digital converter. This unit is 12-bit ± 10.24 V full scale (1 lsb = 5 mV). It was connected in "true differential" mode to minimize noise pickup on the long cables. The ± 10 V output from the PAR and Keithly phase sensitive detectors was thus well suited for direct input into the computer A to D without amplification.

The real time clock was used to time the interval between data points, usually 1 sec or longer. A small correction in timing (1%) had to be introduced in the program to synchronize the rate of the clock with the monochromator scan rate. This discrepancy is probably due to a programming problem rather than to hardware problems with either the clock or scan drive.

The DR11-CK and -M input/output units work with TTL signal levels and are useful for interfacing digital logic such as D-to-A converters and digital meters. The only use in the present experiment is to initiate the scan drive (see below). For other techniques, such as EDC measurement and constant initial state spectroscopy, the digital outputs will be used to drive D-to-A converters controlling the electron energy analyzer. Digital inputs can be used to input digital data from photon counters or DVM's.

The monochromator scan is initiated by loading bit 12_{10} of location 167762_8. A subroutine supplied by RT11 Fortran allows this address to be loaded directly from the Fortran program. To stop the scan, the bit is cleared.

FOOTNOTES AND REFERENCES

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(e) DR11-K Interface User's Guide and Maintenance Manual, DEC order number EK-DR11K-MM-001.

(f) DR11-M General Purpose Unibus Interface User's Manual, DEC order number EK-DR11L-OP-001.

(g) PDP-11 Peripherals Handbook, DEC, 1976.

CAPTIONS TO FIGURES

Fig. 1. Block diagram of the major components of the quantum yield apparatus. Arrows indicate direction of information flow or control.

Fig. 2. Water vapor spectrum (from Ref. 1). Upper part transmittance curve is derived from Ref. 1 with the values of path length 1 mm, vapor pressure 5.1 torr.

Fig. 3. A, exit slit, 2 mm x 10 mm; B, wire coated with sodium salicylate; C, glass window which is fixed with Torr Seal to seal the vacuum; D, photomultiplier; E, housing for a resistor network and electronics circuits; F, plastic (Diflon) coupler; G, LiF window holder having a heater element and a thermistor for temperature monitor; H, LiF window, 1/2" dia., fixed with wax; I, gold mesh grid; J, glass disk wheel; K, plastic (acrylic) disk holder; L, Pyrex glass solution reservoir; M, glass bead thermistor; N, Pyrex glass tube for cooling.

Fig. 4. A, 1/4" stainless steel rotating shaft; B, sliding block; C, outer case for B, which rotation provides the shaft displacement; D, flexible coupling; E, 2:1 speed reducer; F, input axis for a reducer driven by a 60 rpm motor; G, sliding shafts supporting whole the cell assembly; H, thermistor bridge circuit.

Fig. 5. The capacitance is formed by grid electrode 0.5" dia. and liquid film electrode dependence on the distance between them. The ordinate indicates the reciprocal of the capacitance. A, the disk position normally used; B, at this distance often begin the liquid contacts. Abscissa is calibrated from number of turns of the sliding block. Absolute distance from wheel to grid is not measured, since it will vary depending on solution viscosity.

Fig. 6. Block diagram of photoelectron emission current amplifier channel.

Fig. 7. Electrical schematic of bandpass filter. See Ref. 7 for details of component selection.

Fig. 8. Block diagram of photomultiplier output channel.

Fig. 9. Photomultiplier tube current amplifier schematic.

Fig. 10. Photomultiplier tube protection circuit. If output of amplifier exceeds 8 V, the high voltage supply will be interrupted.

Fig. 11. Schematic layout of reference chopper design and electrical schematic of chopper amplifier.

Fig. 12. Schematic of computer controlled relay circuit to start and stop monochromator scan drive motor. Other monochromator controls must be set by operator.

Fig. 13. Block diagram of physical layout of cooling train and control circuitry.

Fig. 14. Thermistor bridge circuit for temperature control. Thermistor has 10 kΩ nominal resistance at $25^{0}C$. Resistance ratio $0^{0}C$ to $50^{0}C$ is 7.5:1.

Fig. 15. Relay circuit controlling gas valve for nitrogen cooling.

Fig. 16. External appearance of hydrogen lamp-shutter-filter-chopper-monochromator assembly.

Fig. 17. A, hydrogen lamp; B, shutter; C, Cajon O-ring connectors (schematic illustration); D, O-ring seal; E, filter assembly (glass, Suprasil, sapphire, open); F, brass retaining plate for G and H; G, LiF window #1; H, entrance slit fixed at 2 mm (actually, slit opening is vertical); I, rotating chopper cylinder; J, stainless steel shafts; K, monochromator entrance; L, mounting plate for M (makes high vacuum seal between lamp assembly and monochromator); M, LiF window #2, fixed to L with Torr Seal; N, chamber for differential pumping of chopper shaft; O, H_2 gas inlet (outlet not shown); P, 1/4" hole for evacuation of chopper chamber (chopper, shutter and H_2 lamp are at same pressure during operation, ca. 500μ H_2).

Fig. 18. General flowchart of program YIELD including data acquisition and plotting.

Fig. 19. Detailed flowchart of data acquisition section of program YIELD.

Fig. 20. Computer configuration.

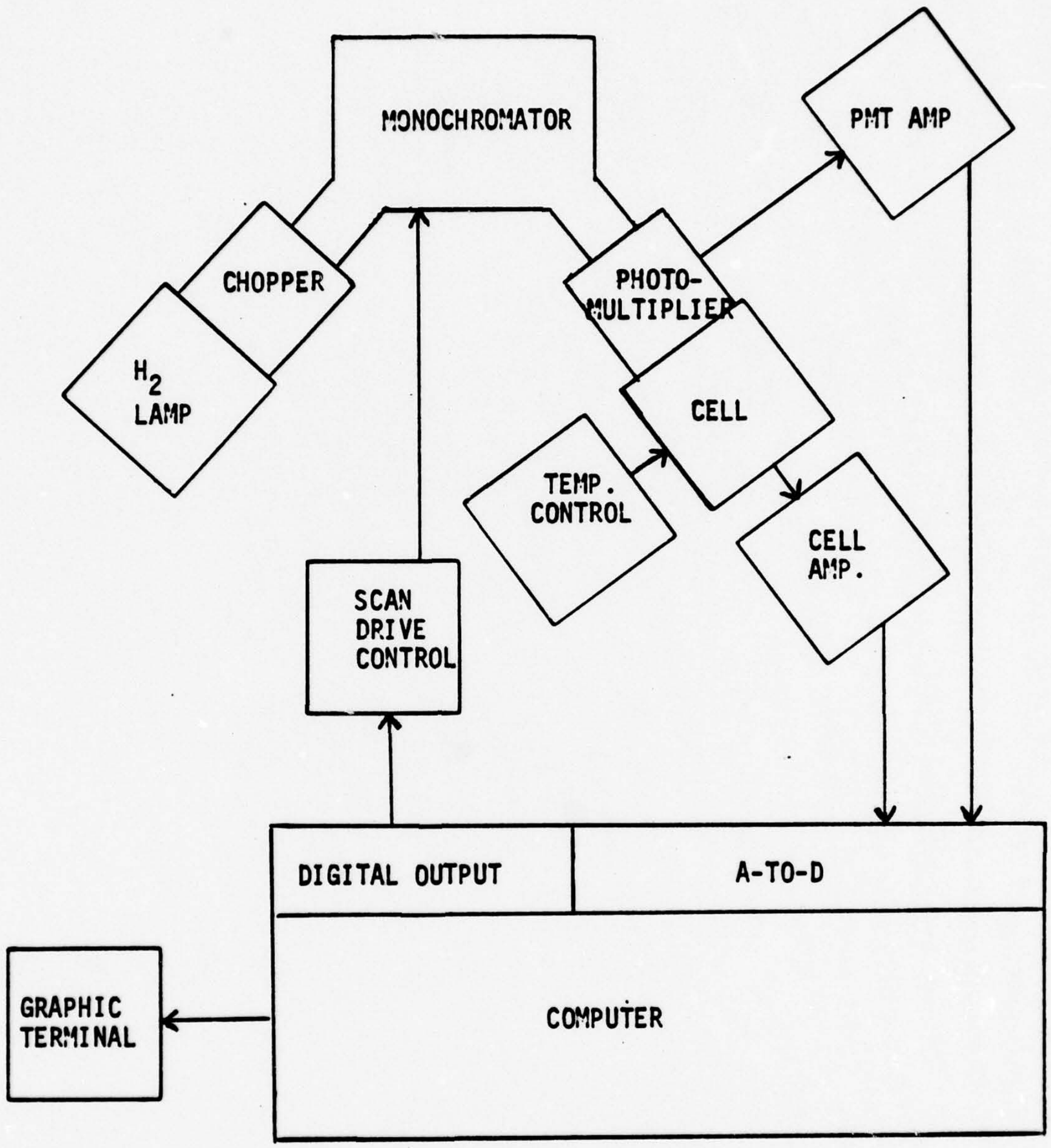
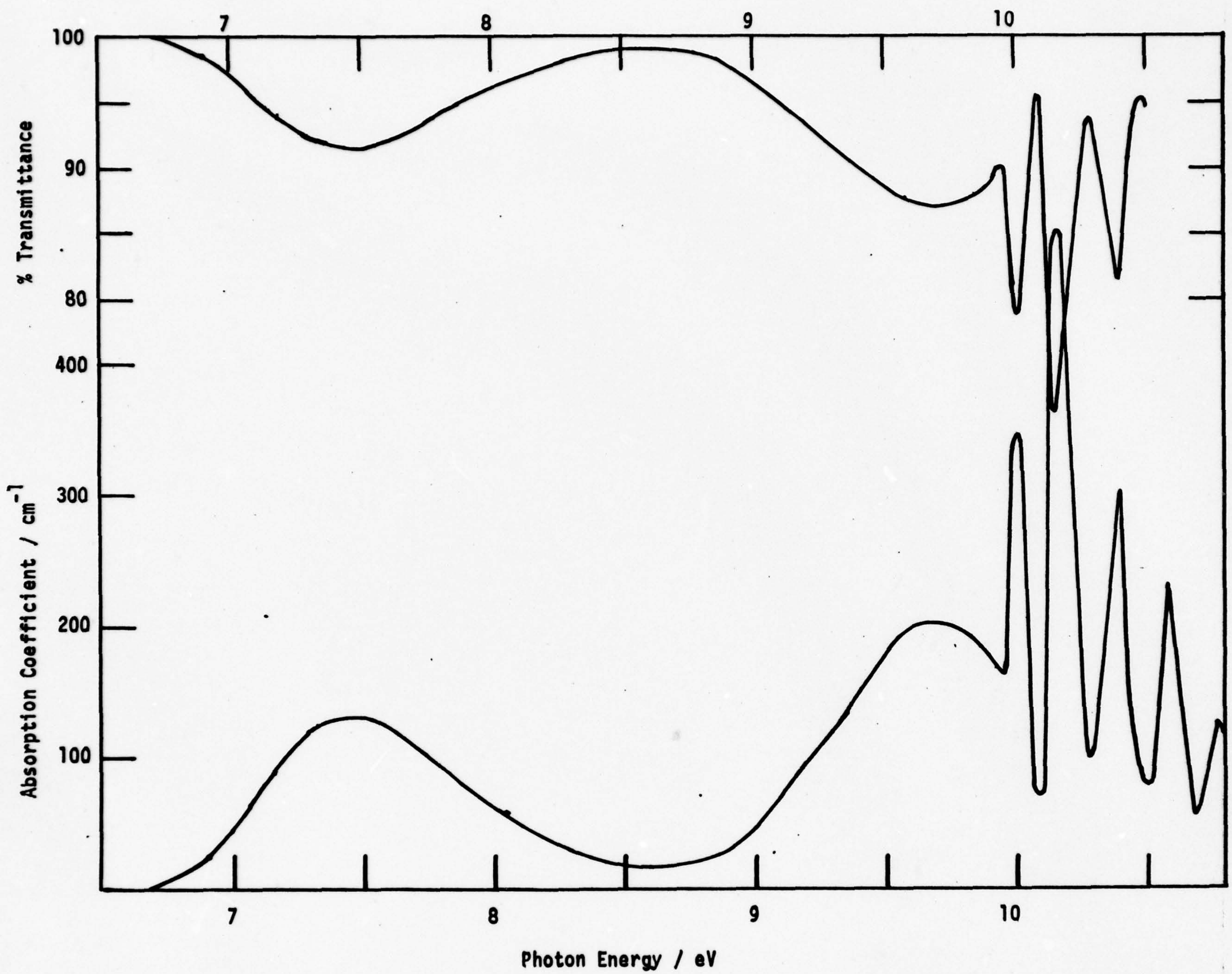

MONOCHROMATOR
PMT AMP
CHOPPER
PHOTO-MULTIPLIER
H_2 LAMP
CELL
TEMP. CONTROL
CELL AMP.
SCAN DRIVE CONTROL
DIGITAL OUTPUT
A-TO-D
GRAPHIC TERMINAL
COMPUTER

FIGURE 1



7
8
9
10
100
90
80
400
300
200
100
% Transmittance
Absorption Coefficient / cm^{-1}
Photon Energy / eV

FIGURE 2

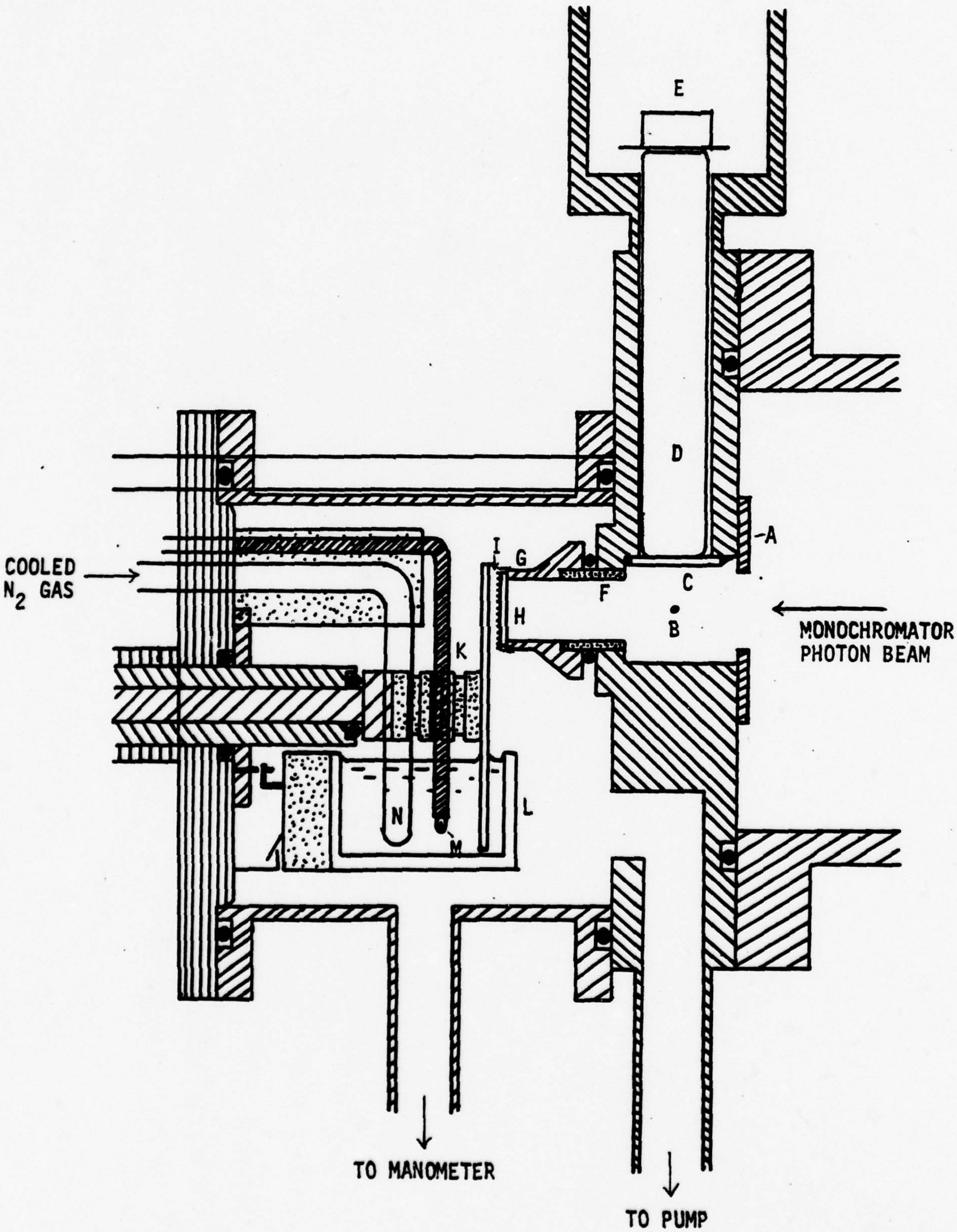

E
D
A
C
COOLED
N_2 GAS
I
G
F
H
B
MONOCHROMATOR
PHOTON BEAM
K
L
N
M
TO MANOMETER
TO PUMP

FIGURE 3

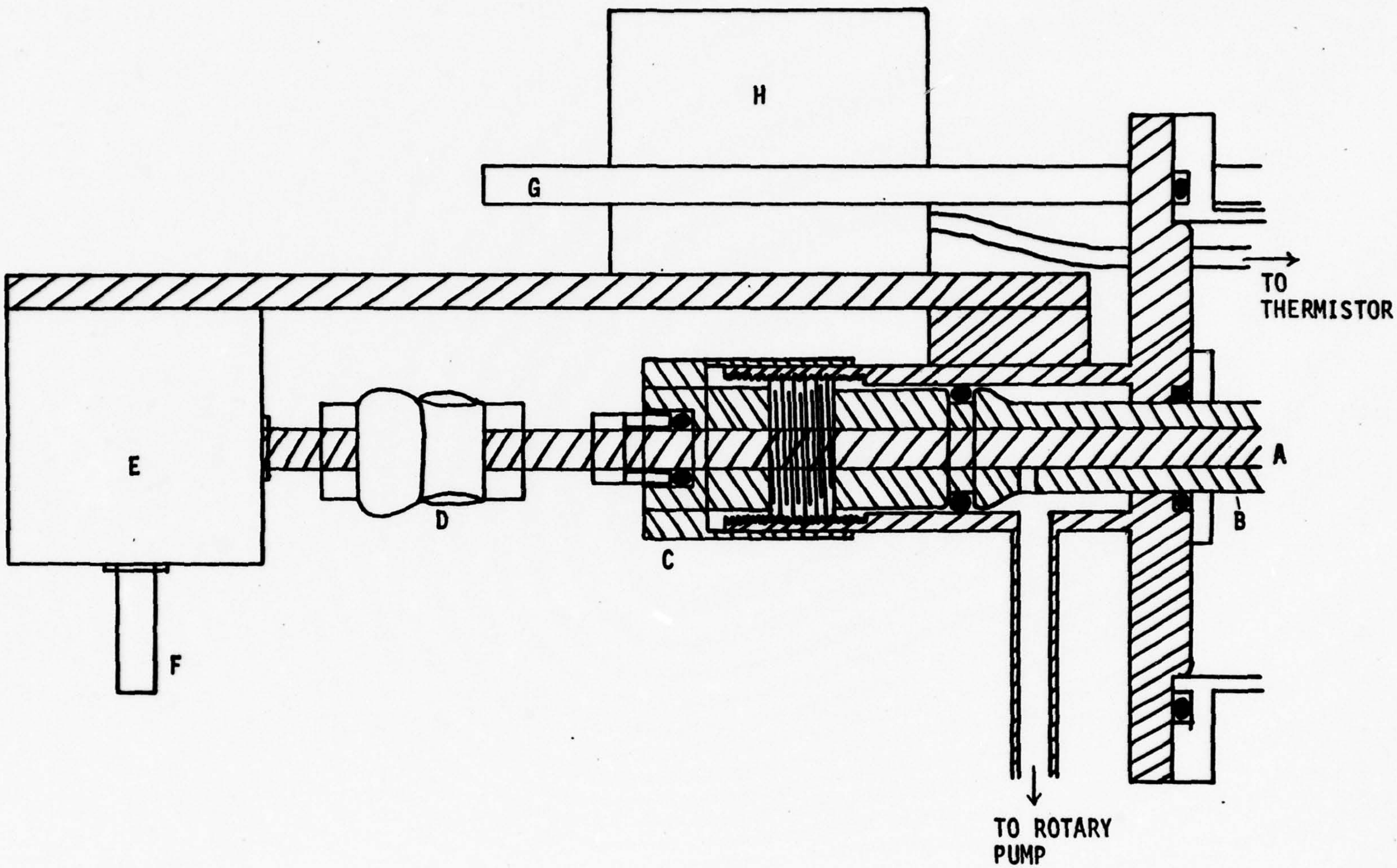


FIGURE 4

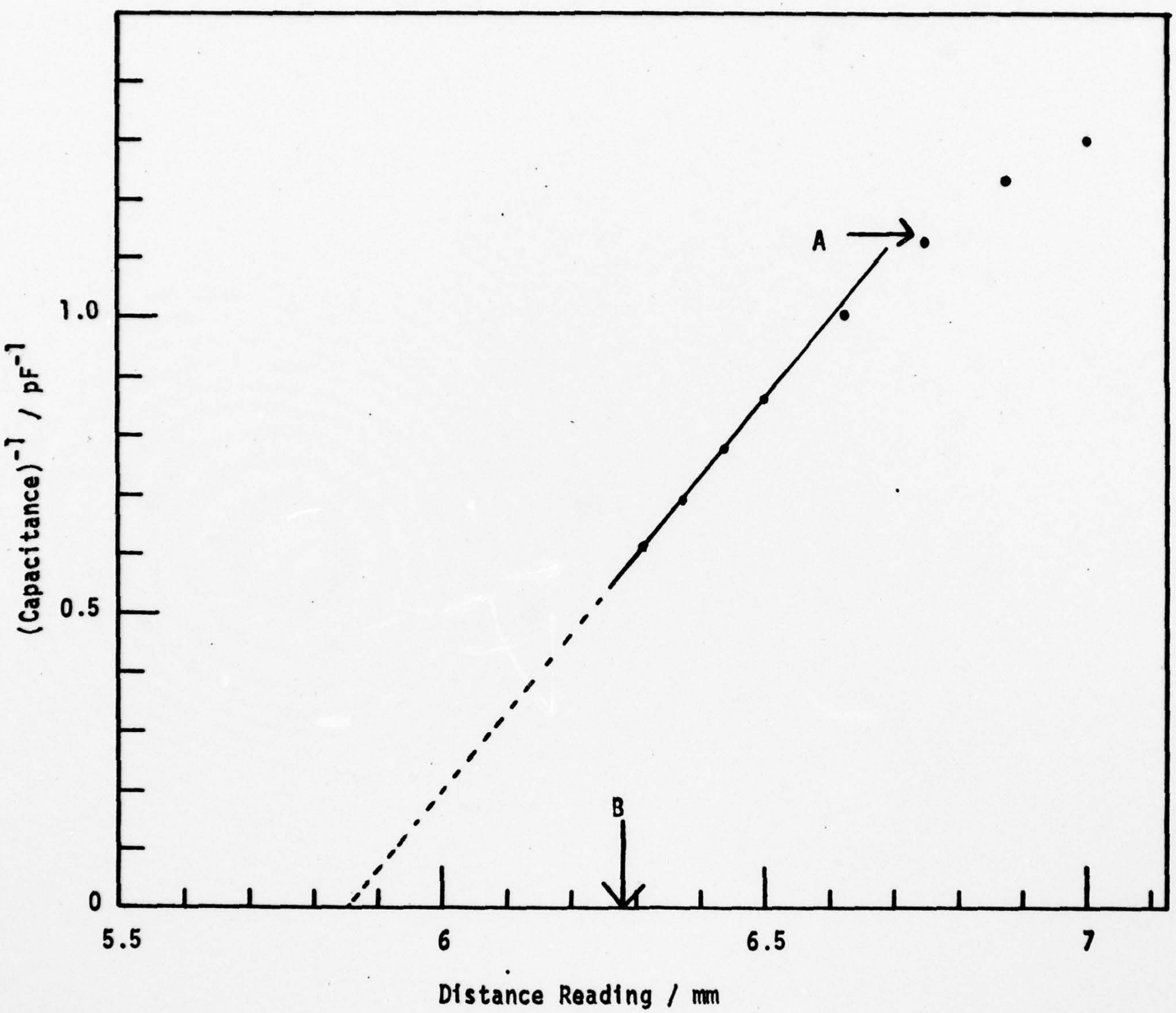
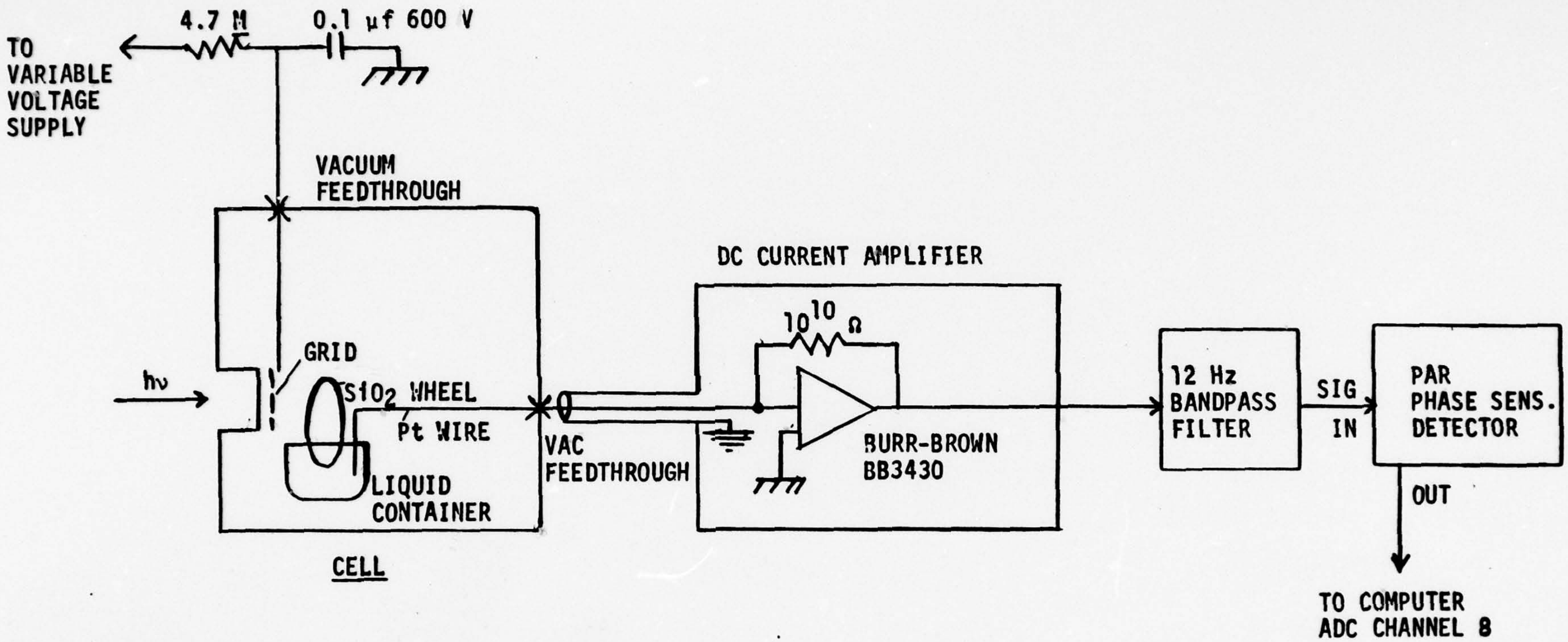


FIGURE 5



TO
VARIABLE
VOLTAGE
SUPPLY
4.7 M
0.1 μf 600 V
VACUUM
FEEDTHROUGH
GRID
hν
SiO2 WHEEL
Pt WIRE
LIQUID
CONTAINER
CELL
VAC
FEEDTHROUGH
DC CURRENT AMPLIFIER
10^10 Ω
BURR-BROWN
BB3430
12 Hz
BANDPASS
FILTER
SIG
IN
PAR
PHASE SENS.
DETECTOR
OUT
TO COMPUTER
ADC CHANNEL 8

FIGURE 6

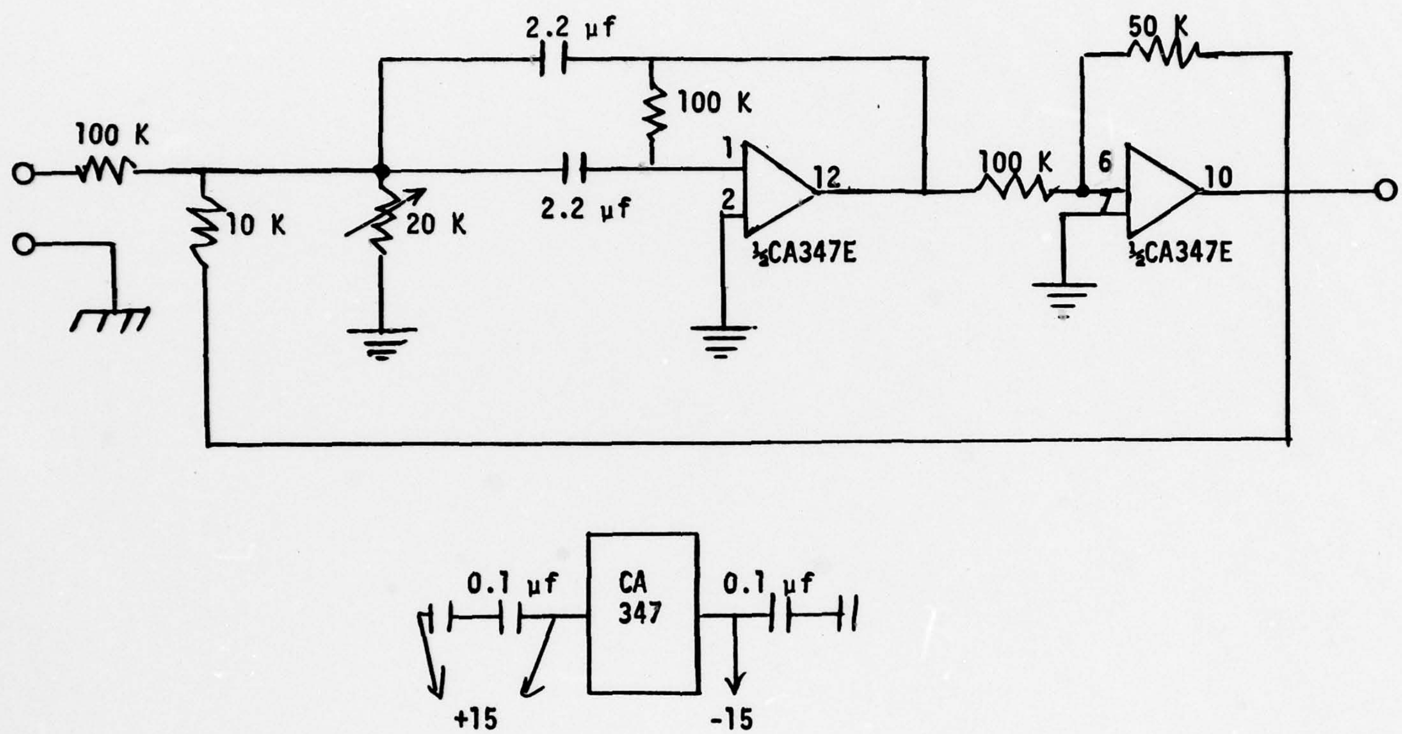

2.2 µf
100 K
100 K
10 K
20 K
2.2 µf
1
2
12
½CA347E
50 K
100 K
6
7
10
½CA347E
0.1 µf
CA
347
0.1 µf
+15
-15

FIGURE 7

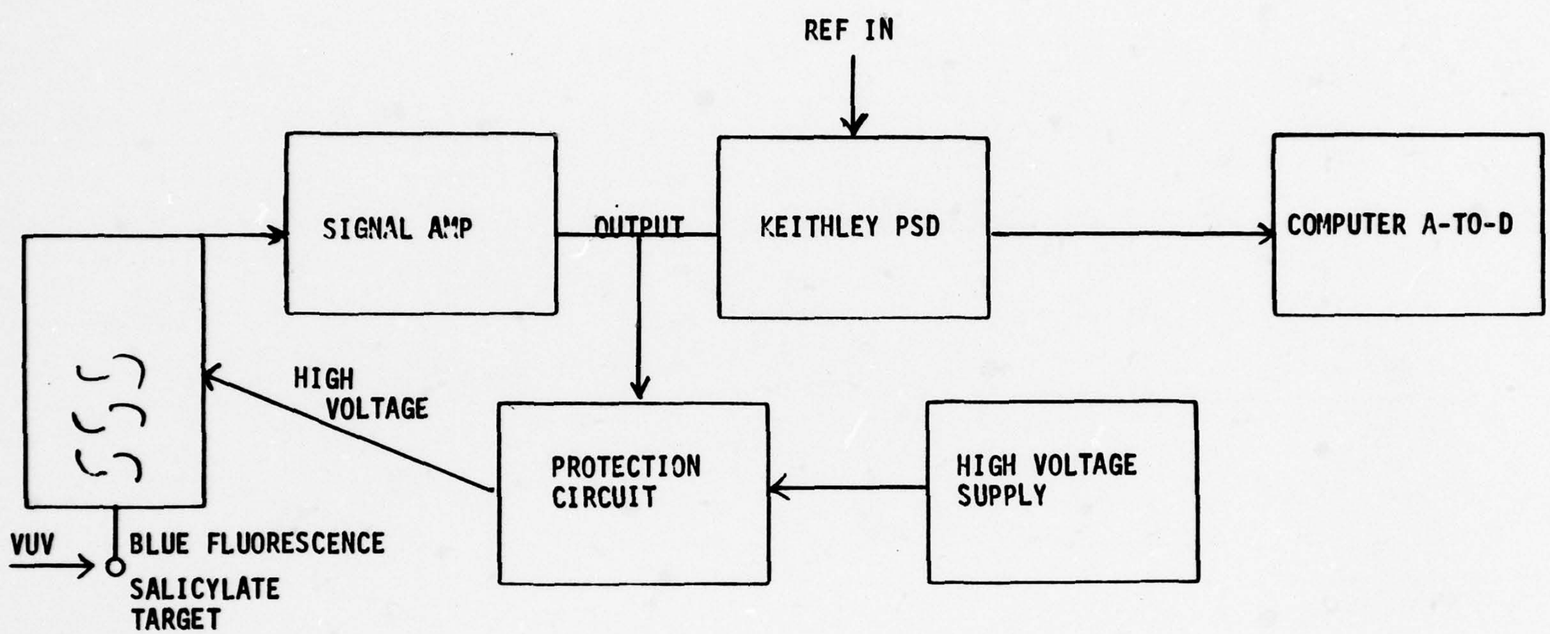
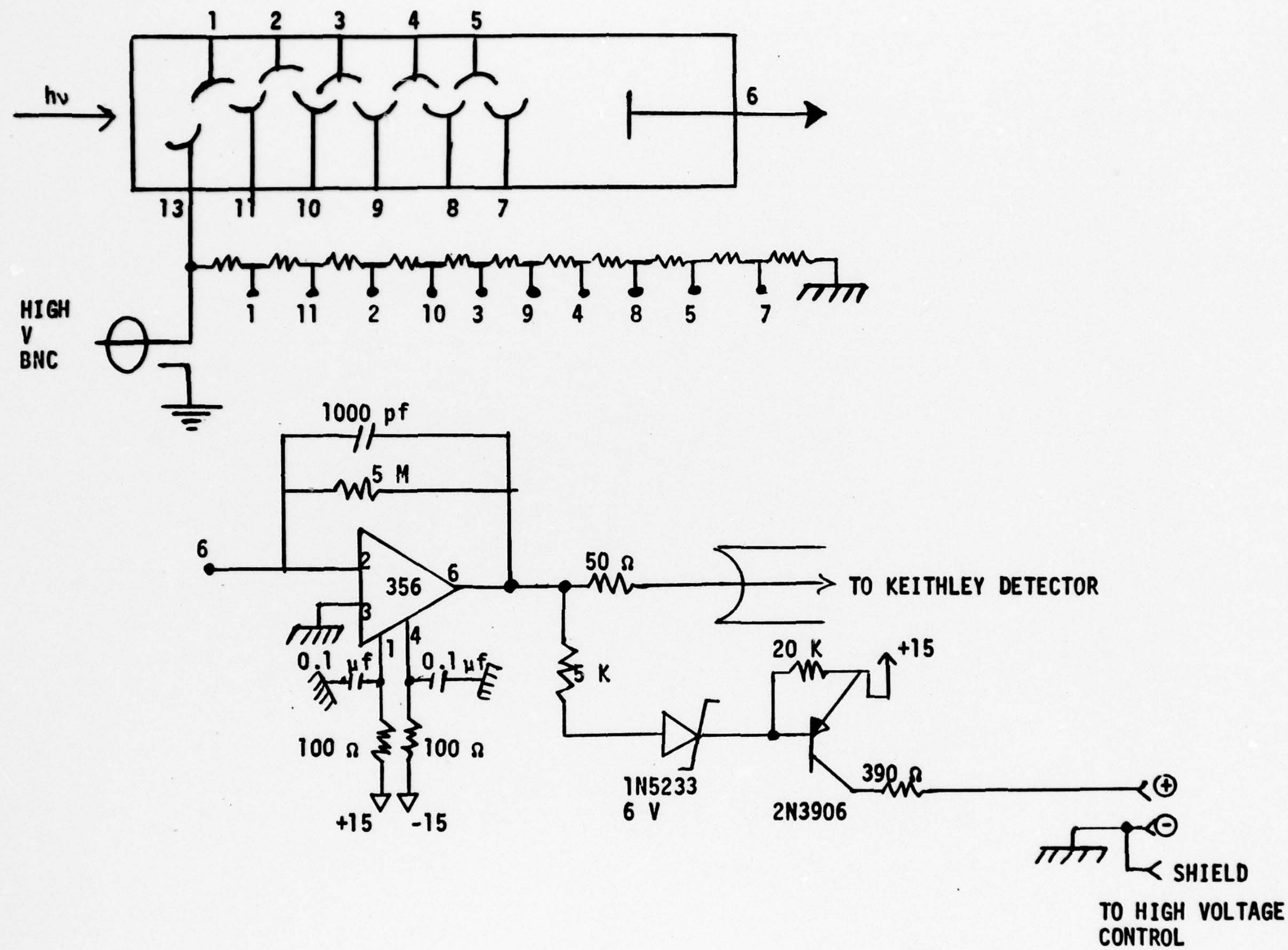
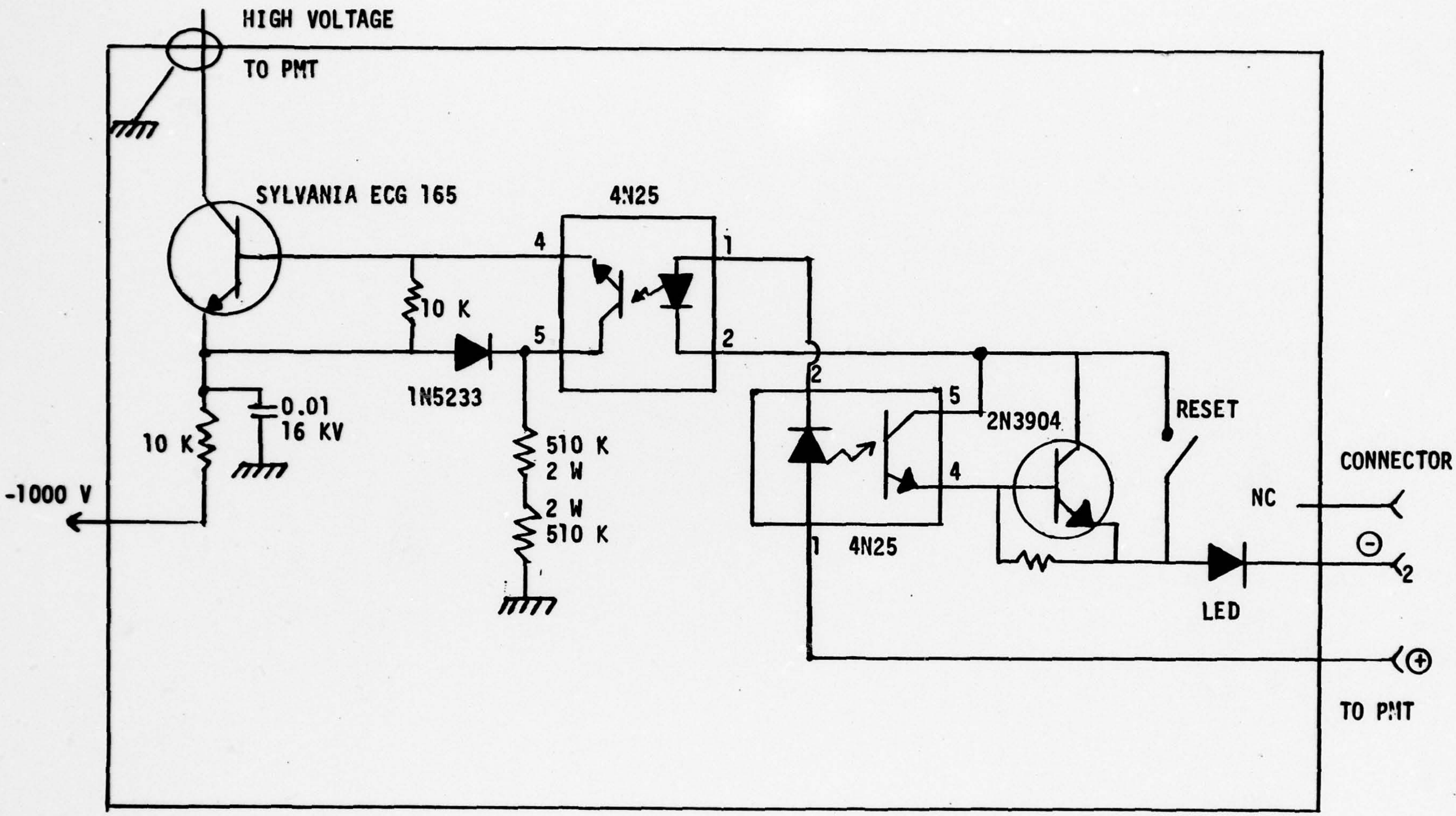

REF IN
SIGNAL AMP
OUTPUT
KEITHLEY PSD
COMPUTER A-TO-D
HIGH
VOLTAGE
PROTECTION
CIRCUIT
HIGH VOLTAGE
SUPPLY
VUV
BLUE FLUORESCENCE
SALICYLATE
TARGET

FIGURE 8



hν
1 2 3 4 5
6
13 11 10 9 8 7
1 11 2 10 3 9 4 8 5 7
HIGH
V
BNC
1000 pf
5 M
6
356
50 Ω
TO KEITHLEY DETECTOR
0.1 μf
0.1 μf
5 K
20 K
+15
100 Ω
100 Ω
+15
-15
1N5233
6 V
2N3906
390 Ω
SHIELD
TO HIGH VOLTAGE
CONTROL

FIGURE 9



HIGH VOLTAGE
TO PMT
SYLVANIA ECG 165
4N25
4
1
10 K
5
2
1N5233
0.01
16 KV
10 K
-1000 V
510 K
2 W
2 W
510 K
2
5
2N3904
RESET
4
1
4N25
CONNECTOR
NC
2
LED
TO PMT

FIGURE 10

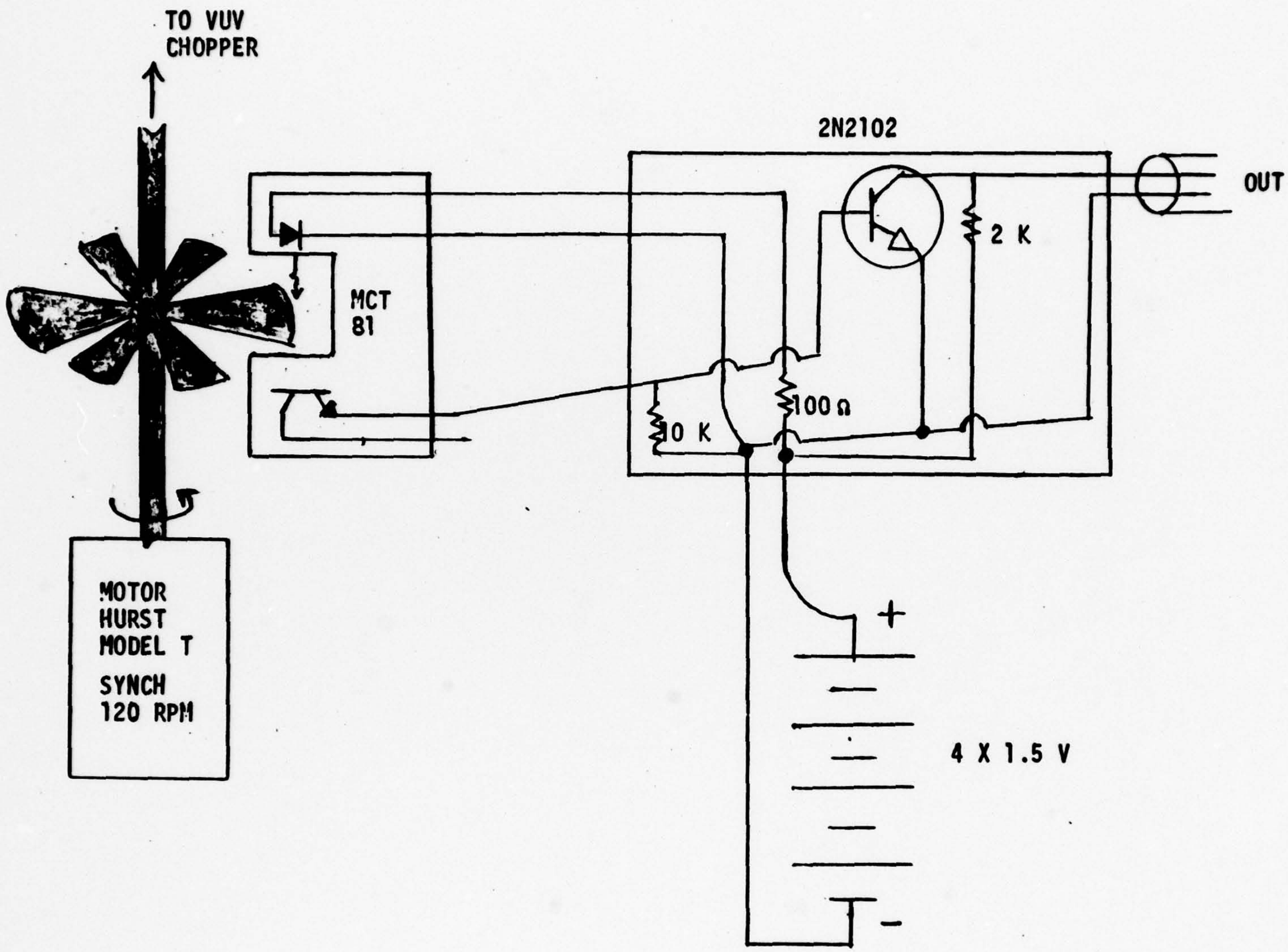
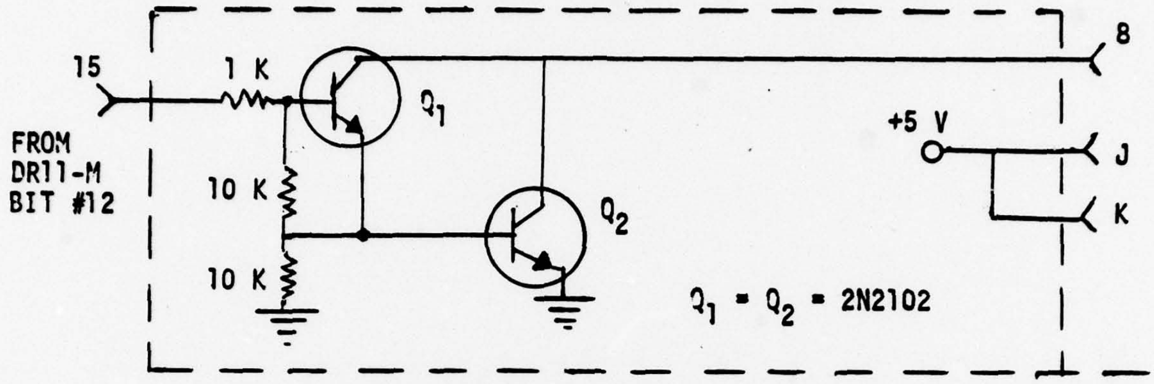
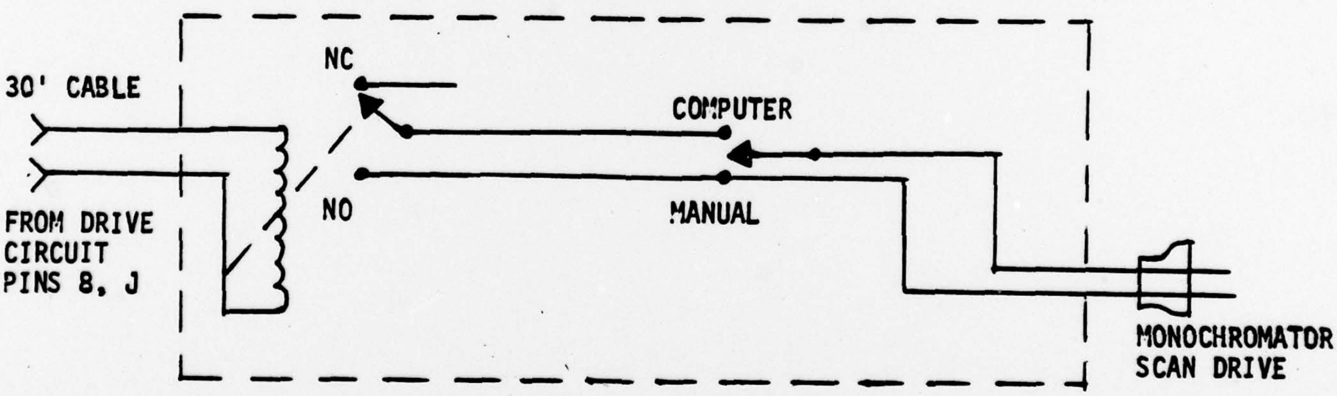

TO VUV
CHOPPER
MCT
81
2N2102
2 K
100 Ω
10 K
OUT
+
-
4 X 1.5 V
MOTOR
HURST
MODEL T
SYNCH
120 RPM

FIGURE 11



DRIVER CIRCUIT (ON DAC BOARD)



SWITCH AND RELAY BOX

FIGURE 12

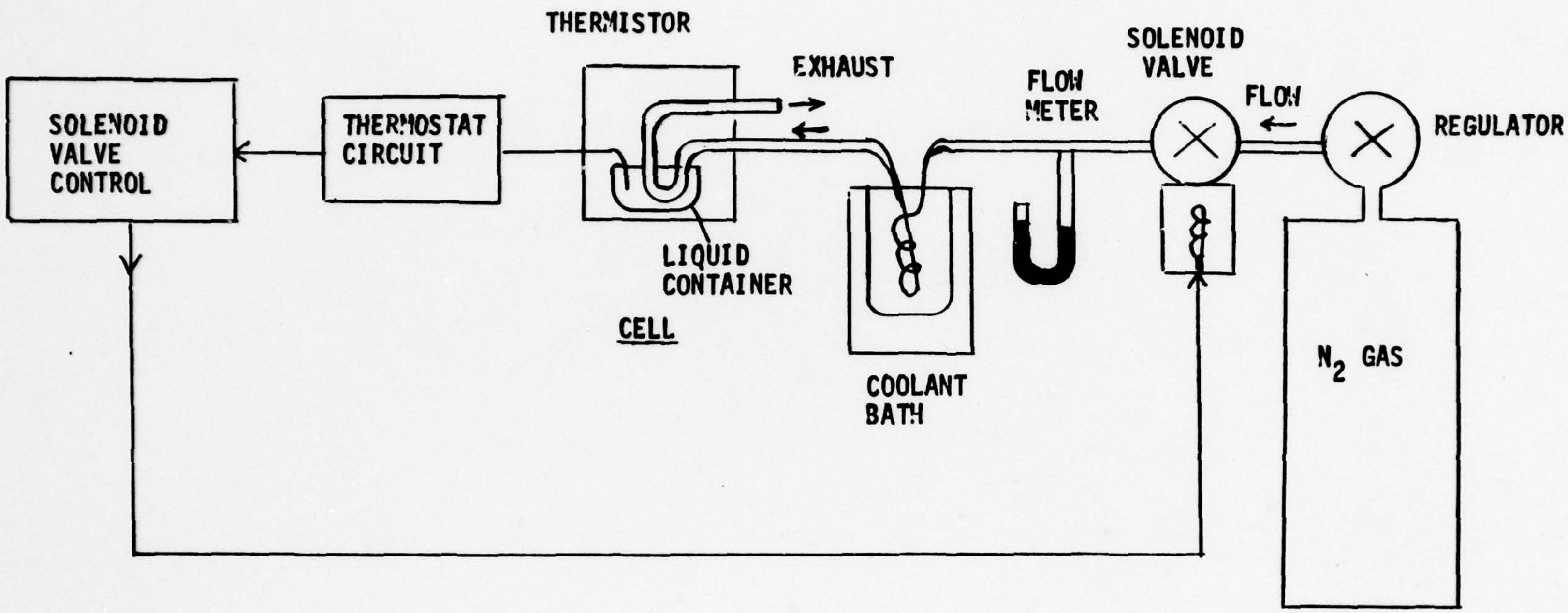

THERMISTOR
EXHAUST
FLOW
METER
SOLENOID
VALVE
FLOW
REGULATOR
SOLENOID
VALVE
CONTROL
THERMOSTAT
CIRCUIT
LIQUID
CONTAINER
CELL
COOLANT
BATH
N_2 GAS

FIGURE 13

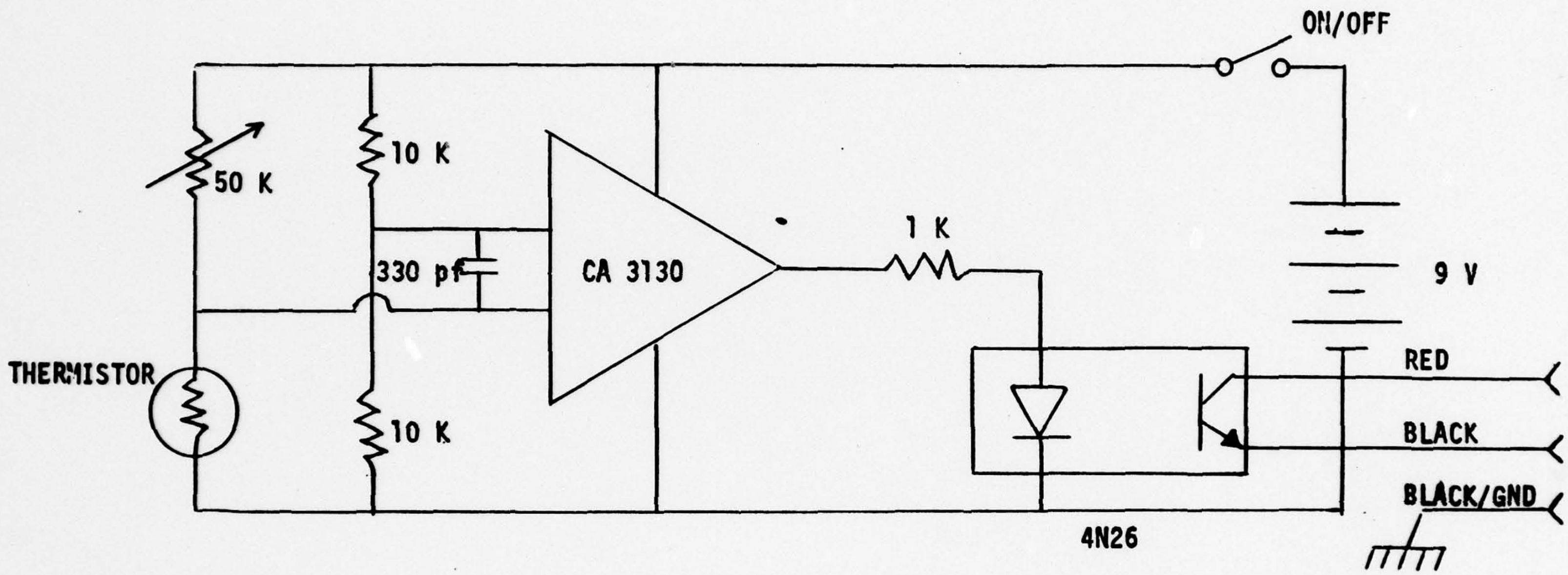

ON/OFF
50 K
10 K
330 pf
CA 3130
1 K
9 V
THERMISTOR
10 K
RED
BLACK
BLACK/GND
4N26

FIGURE 14

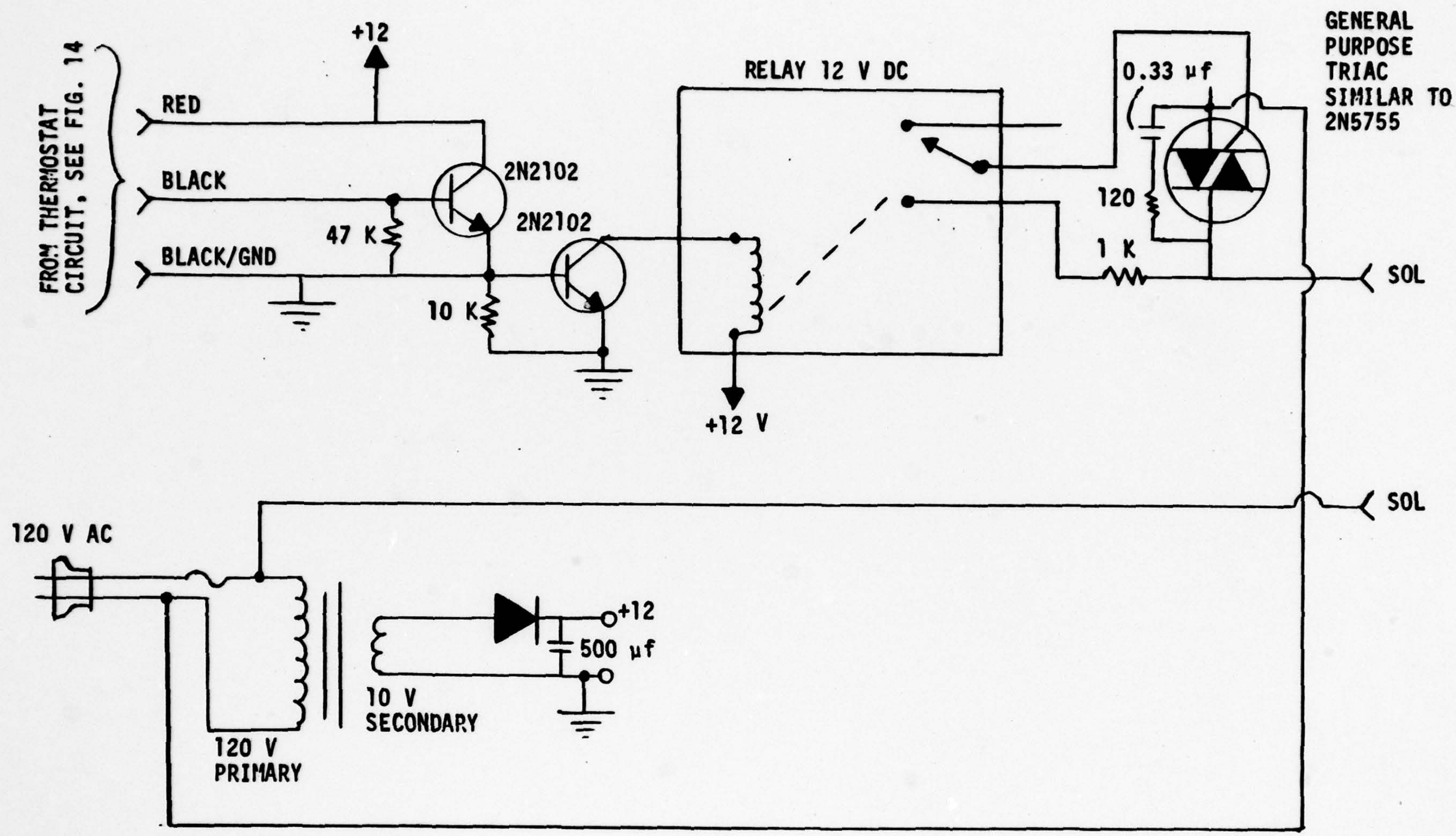
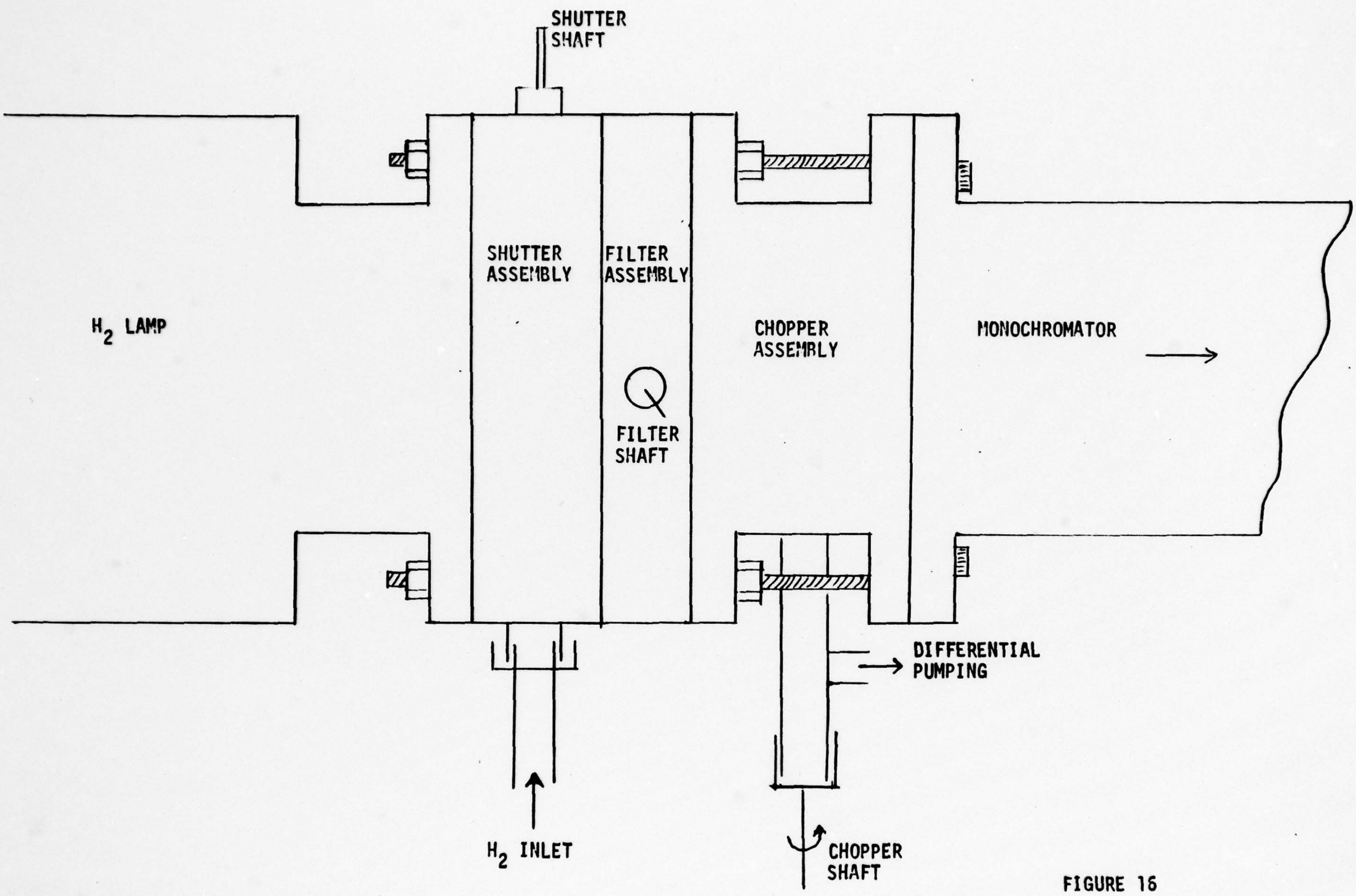

FROM THERMOSTAT CIRCUIT, SEE FIG. 14
RED
BLACK
BLACK/GND
+12
47 K
2N2102
2N2102
10 K
RELAY 12 V DC
+12 V
0.33 µf
120
1 K
GENERAL PURPOSE TRIAC SIMILAR TO 2N5755
SOL
SOL
120 V AC
120 V PRIMARY
10 V SECONDARY
+12
500 µf

FIGURE 15



SHUTTER SHAFT
SHUTTER ASSEMBLY
FILTER ASSEMBLY
H2 LAMP
CHOPPER ASSEMBLY
MONOCHROMATOR
FILTER SHAFT
DIFFERENTIAL PUMPING
H2 INLET
CHOPPER SHAFT

FIGURE 16

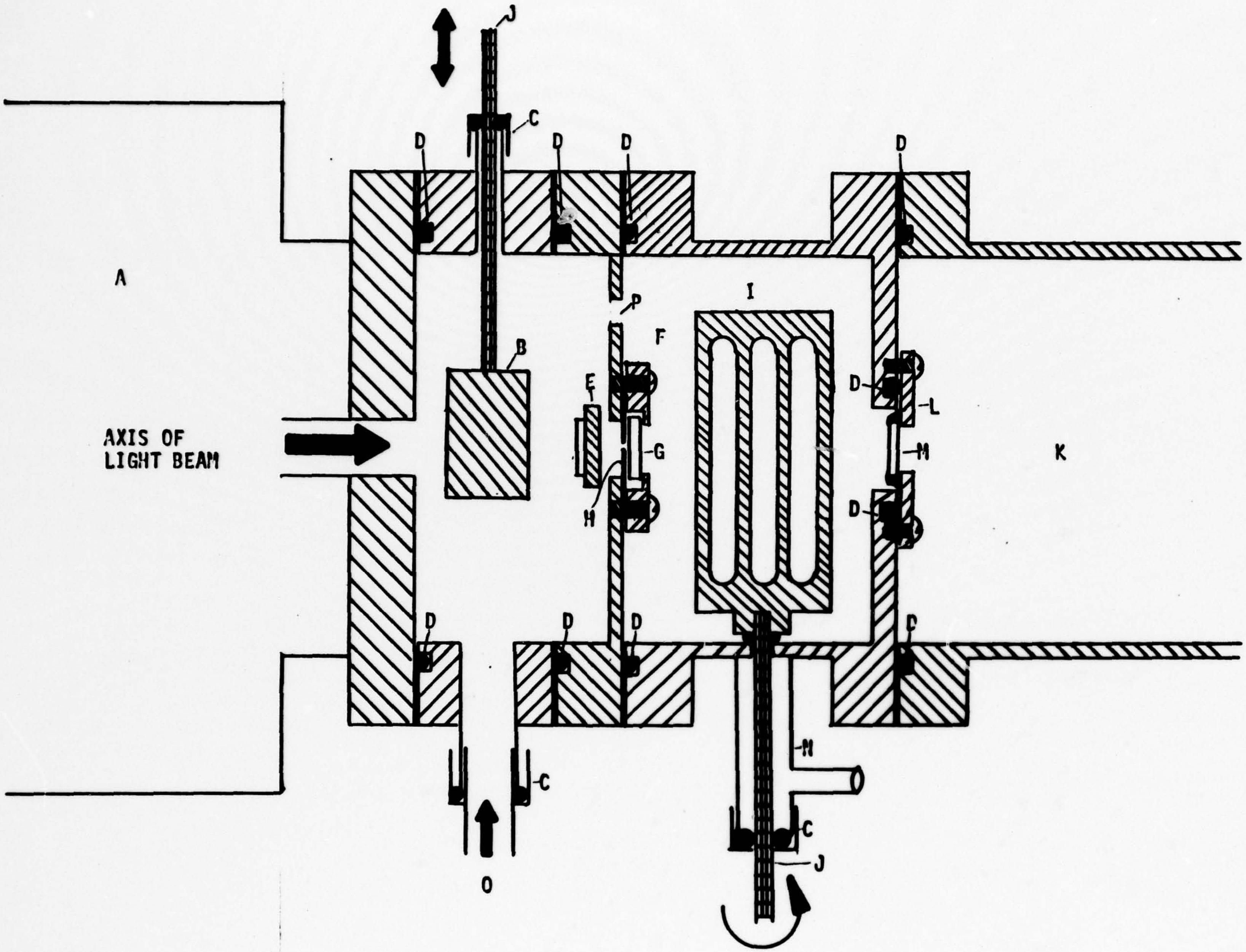


FIGURE 17

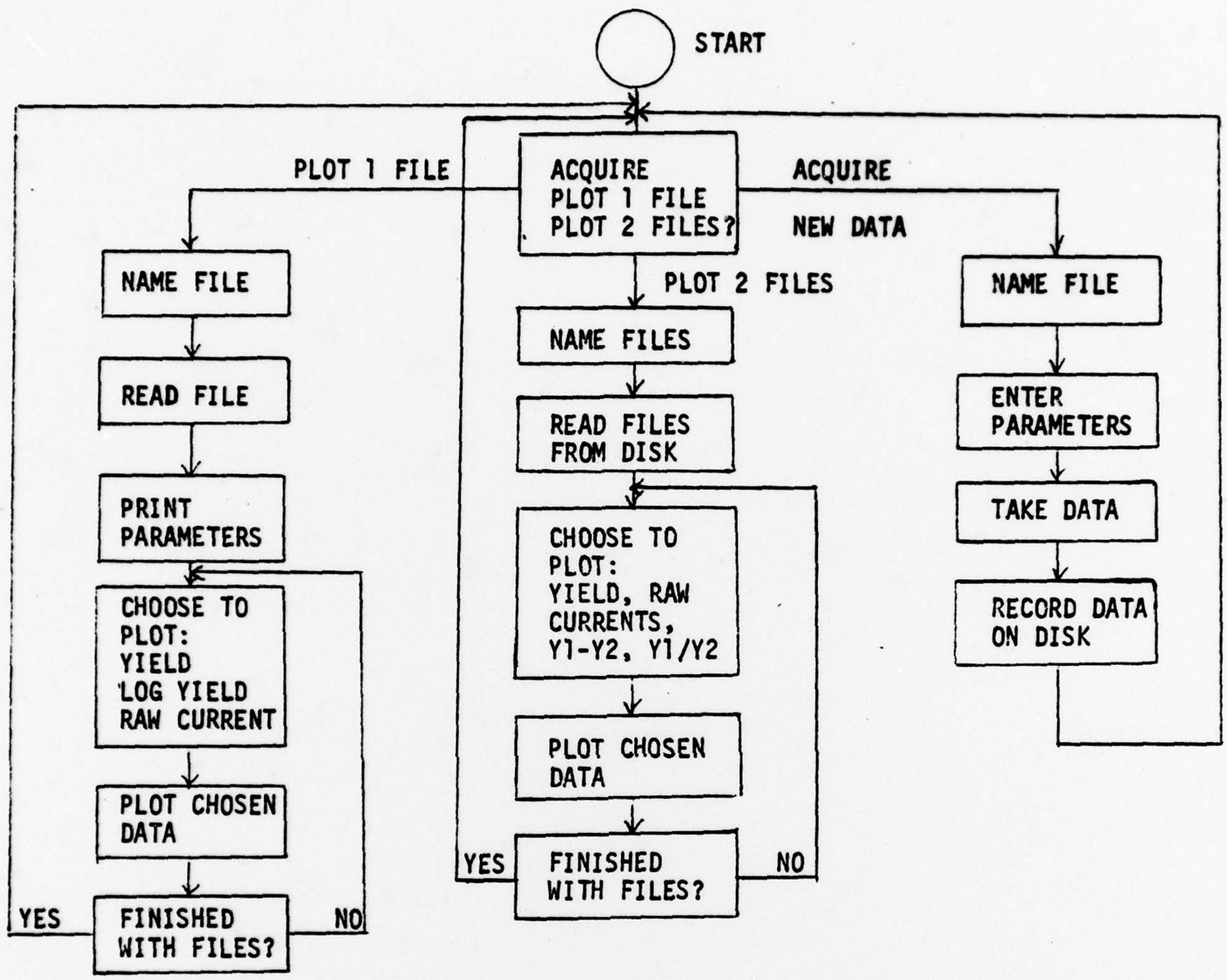

START
PLOT 1 FILE
ACQUIRE
PLOT 1 FILE
PLOT 2 FILES?
ACQUIRE
NEW DATA
NAME FILE
READ FILE
PRINT
PARAMETERS
CHOOSE TO
PLOT:
YIELD
LOG YIELD
RAW CURRENT
PLOT CHOSEN
DATA
YES
FINISHED
WITH FILES?
NO
PLOT 2 FILES
NAME FILES
READ FILES
FROM DISK
CHOOSE TO
PLOT:
YIELD, RAW
CURRENTS,
Y1-Y2, Y1/Y2
PLOT CHOSEN
DATA
YES
FINISHED
WITH FILES?
NO
NAME FILE
ENTER
PARAMETERS
TAKE DATA
RECORD DATA
ON DISK

FIGURE 18

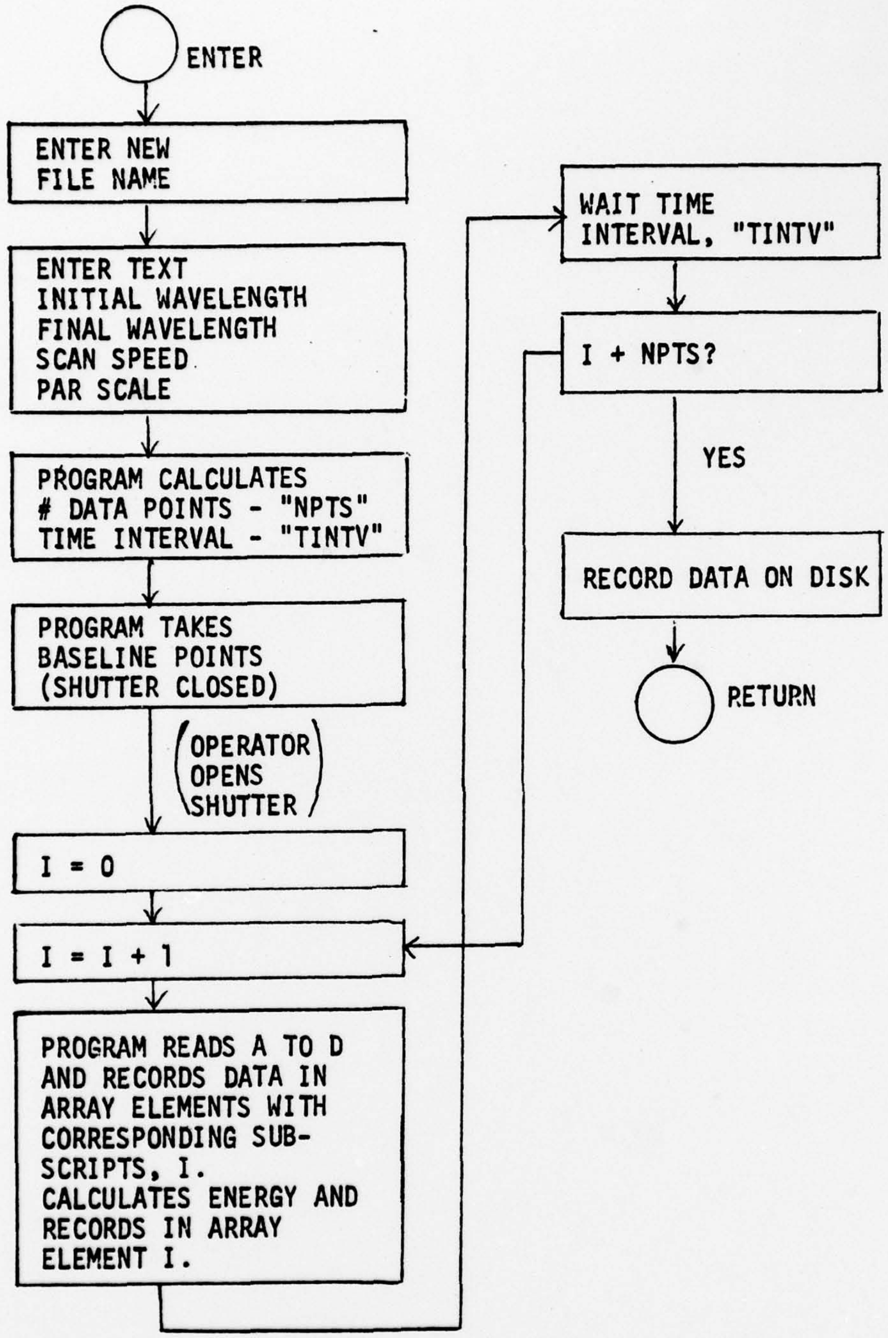

ENTER
ENTER NEW FILE NAME
ENTER TEXT
INITIAL WAVELENGTH
FINAL WAVELENGTH
SCAN SPEED
PAR SCALE
PROGRAM CALCULATES
DATA POINTS - "NPTS"
TIME INTERVAL - "TINTV"
PROGRAM TAKES
BASELINE POINTS
(SHUTTER CLOSED)
(OPERATOR OPENS SHUTTER)
I = 0
I = I + 1
PROGRAM READS A TO D AND RECORDS DATA IN ARRAY ELEMENTS WITH CORRESPONDING SUB-SCRIPTS, I.
CALCULATES ENERGY AND RECORDS IN ARRAY ELEMENT I.
WAIT TIME INTERVAL, "TINTV"
I + NPTS?
YES
RECORD DATA ON DISK
RETURN

FIGURE 19

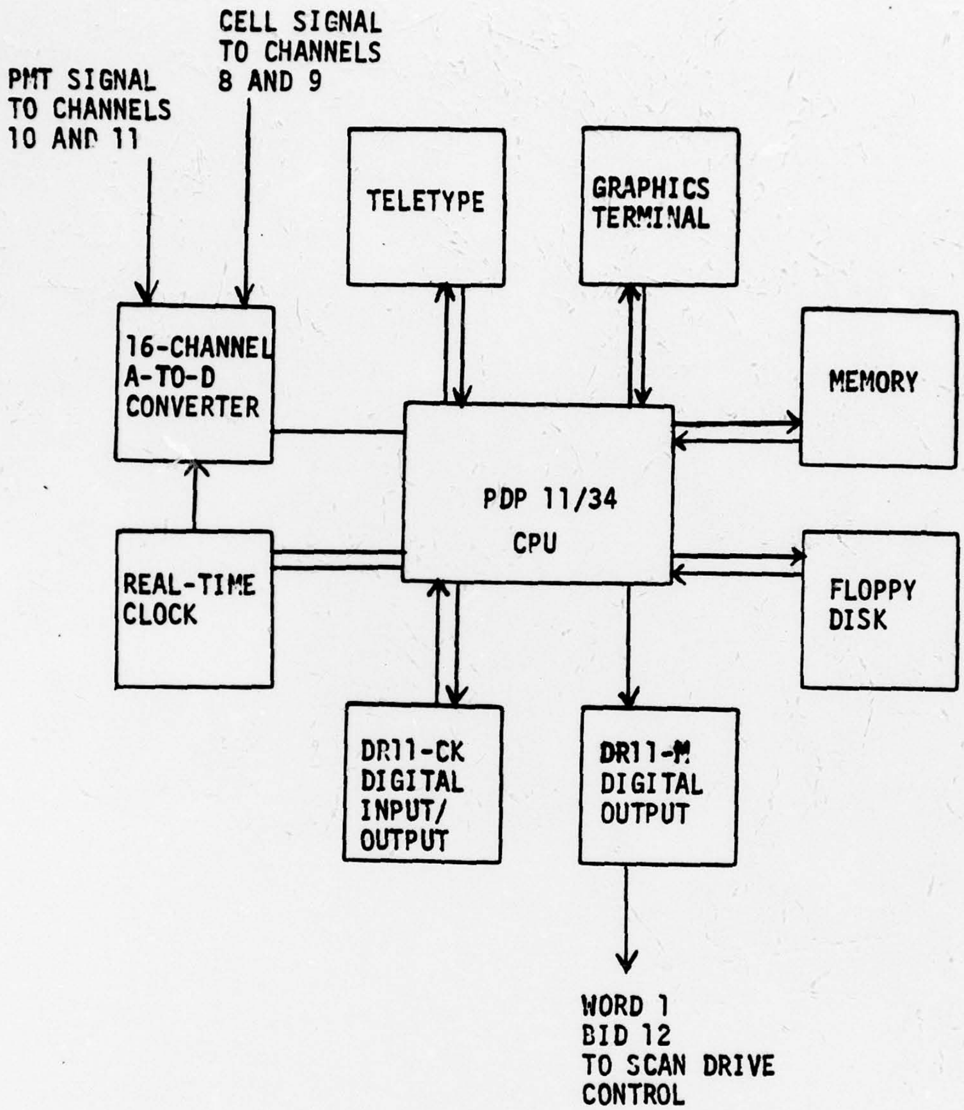

PMT SIGNAL
TO CHANNELS
10 AND 11
CELL SIGNAL
TO CHANNELS
8 AND 9
TELETYPE
GRAPHICS
TERMINAL
16-CHANNEL
A-TO-D
CONVERTER
MEMORY
PDP 11/34
CPU
REAL-TIME
CLOCK
FLOPPY
DISK
DR11-CK
DIGITAL
INPUT/
OUTPUT
DR11-M
DIGITAL
OUTPUT
WORD 1
BID 12
TO SCAN DRIVE
CONTROL

FIGURE 20